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ON THE DEVELOPMENT OF SPECTACLES IN LONDON FROM THE END OF THE SEVENTEENTH CENTURY

(FIRST PAPER ON THE COURT COLLECTION)

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ABSTRACT. We are able to extend our knowledge of the development of spectacles by consulting modern collections, the Court Collection especially. English spectacles before 1666 are very imperfectly known: we can only make inferences about them. After the great fire our knowledge becomes more intimate and we note that horn spectacles with rigid and with split frames are advertised and that unwieldy leather frames (of unknown shape) appear for a short time, together with the then popular "hinged spectacles." Marshall's improvement in grinding and polishing a number of surfaces at the same time must also be mentioned here. In the 18th century the London artisans became the leading spectacle opticians, as they developed the temple spectacles and very efficient nose spectacles in horn and steel or (? preferably) in prepared leather and steel. The authors have tried to collect as much information as possible about these forms and to give their ideas about the outward appearance of the spectacles then in use. Minor inventions also are mentioned and Walker's untenable objections to Wollaston's periscopic spectacles treated. The 19th century was not a favourable period for the master craftsman in London, as large spectacle factories (in Rathenow and in the United States) altered the position of the spectacle vendors.

INTRODUCTION

IT is now nearly five years since—in the Thomas Young Oration of 1923—an attempt was made to bring together the various items of information with regard to the older spectacles; the object was to gain some knowledge as to the sequence of the different important innovations regarding these eye-helps and to present a reliable history of eye-glasses and spectacles. We shall now try to continue this work and hope to fill a number of the gaps left at that time; the reader must be

referred back to previous papers ((6, 7)), as he will find there an exposition of the state of spectacle optics and mounts as it was then known. We intend here, as indicated in the title, to deal particularly with the inventions made by London craftsmen, the more so as such knowledge, especially for the earlier part of the period treated, was rather meagre and unsatisfactory*.

Inferences as to the Oldest State of English Spectacle Manufacture

It would appear ((6), pp. 42, 43) that the old industry in the Netherlands probably spread first to Germany ((6), pp. 44, 45), then to France ((6), p. 42) and to Spain ((6), p. 52), and it will not be too extravagant to suppose that it also sent roots to England, although the designation of the commodity here was not derived from *berillus* as in Germany and partly in France. In any case it will be useful to learn what is known with regard to the outward form of Netherlandish spectacles soon after the invention of printing, for we may well suppose with O. Hallauer that especially after about 1450 the growth of the spectacle industry was favoured. It is very fortunate that a short time ago such an authority as Prof. A. v. Pflugk (4) published his knowledge on this point. From pictures executed in 1466 by the painter Friedrich Herlin in Rothenburg o.d. Tauber we infer that the glasses in the pair of riveted spectacles (Fig. 1) were held after their insertion by mountings of bone (or horn) split at their prolonged parts and fastened by means of threads†. As Herlin had been a pupil of Rogier van der Weyden at Brussels, we may safely assume that we see on his pictures Netherlandish spectacles of about that period.

Bone as the material for spectacle mountings was very largely used in several countries; we know of such use in France (1582), Venice (1585) and Spain (before 1623). In Germany it seems ((6), Ref. 21) as if early in the 16th century bone was being superseded by horn, and there is no doubt that the Regensburg artisans, even in the early days of their craft, used this material along with bone for the spectacle mountings.

It is remarkable that in the South German Free Towns, especially in Nürnberg, the development of methods of spectacle mounting was especially rapid, and that the spectacle makers there seem to have been ahead of many foreign artisans, first with regard to the employment of horn, then of leather, and lastly of metal (and especially wire conveniently worked) for the spectacle mountings. That the Regensburg masters had been very successful in their improvements in the

* I may point out here, as I had nothing to do with the collection of this new material, that the addition to our knowledge with regard to London has been brought about by the indefatigable zeal with which my friend Mr Court has completed his collection. The old shop prints in the first place, but also his notes, cuttings, and advertisements, have furnished splendid evidence on different points and to an extent which I for one had previously considered as lying beyond all hope. Needless to say, I am really proud of my good fortune to work with a collector so superlatively successful.—M. v. R.

† The first reference to this peculiarity in the mounting was given some time ago by Dr J. M. Simon.

mountings has already been stated ((6), p. 47). It will become necessary to refer to this statement in one of the following paragraphs of this paper.

With regard to the English spectacle trade in the 16th century, very little is known beyond its bare existence, but we may refer to a previous paper ((7), pp. 182, 183), where an attempt was made to learn something about the forms of spectacles by discussing some terms used in Shakespeare's works and connecting them with descriptions by W. Bourne in 1585. If we allow such indirect evidence, we may suppose that on the eve of the 17th century two principal forms of eye-helps for distant vision were used in England; the perspective glass held before a single

Fig. 1. A pair of Netherlandish spectacles of the middle of the 15th century, painted by Fr. Herlin; after Prof. A. v. Pflugk (4)

eye for the higher classes and (possibly) binocular glasses (= spectacles) for the lower classes. We do not, however, know anything as to the outward form of these binocular glasses; in particular we do not know whether they were bow or riveted spectacles.

As to reading glasses we may refer to the two portraits painted by H. Holbein in the first part of the 16th century; they are reproduced by Madame Heymann ((6), Ref. 55, planches 2 and 3 of the first part). As they represent high dignitaries, we obtain a glimpse of the early form of reading spectacles used by wealthy men in England. They seem to have been mounted in horn with rigid bows and were—at least in Thomas Morus's case—applied far down the nose. We do not, however, know the place where they were bought.

There is no doubt that the city artisans producing eye-helps of either sort were rather numerous in the beginning of the 17th century*, for, as pointed out already ((6), p. 62), a company beginning with not less than twelve functionaries will have included quite a number of freemen.

It is a pity that we have not been able to find a contemporary print of the old coat of arms of 1629 of the Spectacle Makers' Company. There is a tradition that there were three pairs of bow spectacles on the escutcheon with the legend "a blessing to the aged," but we are by no means sure that this representation goes far back into the 17th century†. From the legend we may infer that presbyopes and possibly also hypermetropes were helped by the spectacle makers, and this supposition is in harmony with the conclusions we may draw ((6), p. 48) from the well-known Regensburg and Nürnberg masterpieces from the 16th century onwards.

As, unfortunately, London spectacles are so seldom mentioned or described in the interval between 1629, the year of the charter, and the great fire in 1666, the following title of a theological pamphlet in the Court Collection is of interest:

A prospective Glasse, wherein The Child in understanding is enabled to see what the wicked Counsellours did above twenty years ago (To maintain the Protestant Religion:) as clearly as the Man can see what they have done these 3. years past for the same pretended end, with the helpe of Chrystall Spectacles. (Printed 1644.)

There may be some doubt as to the real meaning of a *prospective glasse*; we do not believe that it must be necessarily understood as a Galilean telescope at so early a time, but we think it rather means a single eye-glass or *perspective glass*. In order to understand more fully the idea of the writer of that title, we must recall the fact ((6), p. 46) that the spectacle glasses were divided into negative or *young* glasses (for young or short-sighted people) to enable them to see at great distances, and positive or *old* glasses to enable the wearers to look at near things. As the negative glasses were preferably used as single glasses even far into the 18th century, we find the singular number "prospective glass" in our case; the positive glasses for reading or working were mostly binocular or had the form of spectacles. The writer of the title compares "the child in understanding" with the wearer of a *young* glass: in order to look so far back as above twenty years, a "prospective glasse" is necessary. The man (in understanding), who wishes to look back three years only, wants a pair of spectacles. From the concluding sentence we may safely infer that quartz lenses were well known in England at that time and considered as especially effective. That is in the best possible harmony with the professional views prevalent in the Low Countries and in Venice from the beginning of the 17th century.

* H. Sirturus mentioned on p. 54 of his book of 1618 that the spectacle makers (*spicillorum artifices*) in Spain, France, and England used tin ashes after tripoly for polishing.

† In another paper we intend treating more fully the question of the Spectacle Makers' Company's coat of arms.

The Usual Nose Spectacles in the 17th Century

Nothing being known with certainty with regard to the old coat of arms of the Spectacle Makers' Company, we must the more deplore the loss occasioned by the great fire of 1666, when all the books of the Company were burned. We cannot expect to obtain any evidence before that time, as other means of learning details about the outward form of spectacles and eye-glasses (pictures of wearers of spectacles between 1629 and 1666 for instance) do not seem to be forthcoming.

After 1666 we get some evidence with regard to spectacles both by remarks in the Company's books and—even more fully—by the shop prints of some prominent members of the Company.

As to the first means of information we shall restrict ourselves to one reference ((10), p. 41), but we hope to go more fully into such remarks when we publish our second paper on the Court Collection. From the reference just given it becomes evident that in 1671—only five years after the great fire—French spectacles were imported in rather large numbers, and we may conclude that their tin mountings distinguished them from English spectacles, as they certainly did from contemporary South German ones. Although we have no direct evidence of that time as to the form of general spectacles made by the London masters, soon afterwards, in 1675, a shop for optical goods was opened by Yarwell, the shop print (Fig. 2) of which has fortunately been saved. Here we find a kind of bow mounting in tortoiseshell or horn with a clever device for imparting elasticity to the bow (Fig. 3). Fortunately the Jena Collection is in possession of an old horn frame slit four times (Fig. 4)*. One of the bows is broken, the ends being visible in the figure. It is possible that this is actually a pair of the old English slit spectacles as they evidently looked like this specimen. We hope to find a similar specimen in England in order to confirm this supposition. We do not know the exact date of the shop print, but we may safely ascribe it to 1680 or the years immediately following, Yarwell's life being sufficiently well known to us, as our second paper will show. We should not have been able to understand the device common to the spectacles in the four corners, had not by good fortune a remark in the Spectacle Makers' Company's books thrown some light on the subject.

In a note regarding the imposition of fines we find the following prices (probably retail prices) for different kinds of spectacles†:

> Black frames valued at 5*d*. per pair.
> Black slit frames valued at 1*s*. 4*d*. per pair.
> Four slit frames valued at 2*s*. 1*d*. per pair.
> Ordinary white spectacles valued at 7*d*. per pair.

We may take for granted that these prices belong to the end of the 17th century, as there is no mention of the important innovation of leather spectacles brought about at that time. In discussing this short price list we may safely assume that the cheap ordinary white spectacles were mounted in metal; a specimen of this

* The scales on Figs. 4, 8, 10, 11, 12, and 17 are in centimetres.

† It may be useful to compare the retail prices paid for a pair of spectacles about 200 ((6), p. 45) and about 170 years ((6), p. 46) before; they do not reach 10 farthings.

Fig. 2. Yarwell's shop print of 1675 or later with the four pairs of split spectacles in the corners; from the Court Collection

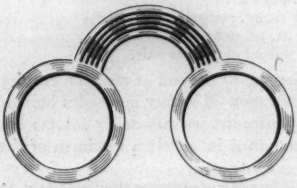

Fig. 3. A pair of split spectacles, reconstructed after Yarwell's shop print of 1675

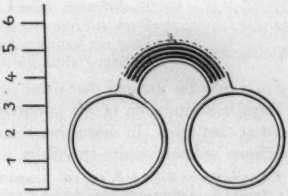

Fig. 4. A pair of split spectacles (damaged); from the Jena Collection

kind of mounting is, we think, to be seen in the lawyer's hands in Hogarth's *Marriage à la mode*. The "black" frames mentioned above are in our opinion made of horn, the well known and, we may say, orthodox material for spectacle mountings at that time. There is, fortunately, direct evidence with regard to this in a shop print of John Marshall brought out after 1694. We shall give the text later on when treating of the introduction of leather spectacles. It will suffice here to point out that he mentions as the current forms of spectacles "such with horn and tortoise-shell frames," where the horn frames may coincide with the black frames of our list above. The cheapest form of these we conceive to have had a stiff bow, whereas this part was slit or divided into (two) thinner strips for the glasses of medium price and into four or five strips for the most expensive ones. The four pairs of spectacles on Yarwell's shop print evidently belong to the expensive four-slit class (executed there apparently in tortoiseshell) and illustrate the above expression in the Company's books in the most satisfactory manner.

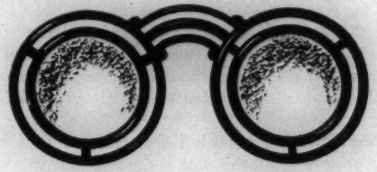

Fig. 5. "Split" spectacles in the Regensburg by-laws of about 1550; after (6), p. 47, Fig. 2

This kind of horn mounting (Fig. 5) first occurs in our experience—as hinted above—in the Regensburg laws and by-laws of about 1550 and has already been shown ((6), p. 47, Fig. 2). We do not mean to suggest that they were made in London necessarily after a Regensburg model. Unfortunately the handicraft in the Netherlands during this intermediate period is as yet very imperfectly known, and it is not possible for us to follow the gradual development of this idea. A mere statement of a case of priority must suffice here.

Although these improved and rather costly specimens had evidently a somewhat clumsy appearance, they were considered, as we shall show presently, as the old and correct form in contradistinction to the new kind of leather spectacles. They appear—not seldom with the critical inscription "The Right True"—on different signs well into the 18th century, that is, until a period when these pieces were certainly out of general use*. We may consider them as remnants of a tradition handed down by aged artisans to the younger generation of spectacle makers and examples of a comparatively early state of the craft.

* In certain cases they were probably asked for much later. T. Ribright, for example, offered *split* spectacles between 1750 and 1760.

Some Improvements in the Working of the Spectacle Glasses and Innovations in the Mounting (Leather and Folding Frames)

During the latter part of the 17th century a closer connection seems to have existed between men of science and some of the London opticians, and in consequence the work of these opticians became better and more accurate. A very important instance of this relation is to be found in John Marshall's method of grinding and polishing a great number of lenses or "optick glasses" at the same time and on the same tool.

It may not be out of place to give some account of the old manner of grinding and polishing optical surfaces. An early description is to be found in the work of H. Sirturus ((6), Ref. 34) in 1618, who tells us of the manner then used by the Venetian glass grinders. We learn that the tools were made of iron, that the lens was first fixed with pitch to a wooden handle, and later with plaster to a stone covering plate of the wooden handle, and that it was rubbed against a stationary grinding tool. As the Venetian experience of working glass surfaces was acknowledged everywhere (Venetian mirrors were at that time and later deservedly appreciated) we may infer that this method of figuring was the one used generally and that it was the one used in London when the Spectacle Makers' Company was formed.

The improvement, which was made before the year 1694, was described by Marshall in a shop print of about this date in the following words: "Who hath the Approbation of the Royal Society for grinding spectacles true in Brass Tools, the way of grinding being quite different from the Method used by other Spectacle-makers." We know from other contemporaneous shop prints, e.g. those of R. Sterrop and J. Yarwell, of G. Willdey and T. Brandreth, that this method spread very rapidly among the spectacle makers of the metropolis. We cannot wonder at that, as the apprentices of Marshall and the other opticians named above will have taught as freemen this method to their brother journeymen and their own apprentices.

This excellent method of surfacing spheres of not too short a radius gave the London optician a great advantage over his foreign brethren: it was, according to W. H. Wollaston's statement in 1812, in the possession of every journeyman optician in London; it does not seem to have been used on the Continent before the end of the 18th century, and it may have been first practised in Venice (Fig. 6), but our knowledge of the extension of such technicalities over different countries is by no means very reliable, as workshop methods were generally held strictly secret.

About the end of the 17th century some of the more advanced London opticians tried to introduce plano-convex instead of bi-convex spectacles, but they encountered the very energetic opposition of the Company and its officers. Judging from our modern standpoint, the plano-convex form is decidedly to be preferred, as the astigmatism of oblique pencils in looking through the glass with the natural movement of the eye is diminished in comparison with that produced by any

bi-convex form. The freemen of the guild, however, objected to this form, because the old rules were against any advantage that one of the brethren might obtain by making a form of glass which was more easily finished than the bi-convex glasses ordinarily in use. We do not know for a certainty the result of this difference of opinion. If we may judge from the standpoint defended by W. Jones in his argument with W. H. Wollaston, this step in the right direction met with no better success than the much earlier suggestion for the employment of this same plano-convex and plano-concave form put forward by M. A. de Dominis in 1611 and by B. Daza de Valdes in 1623.

Before dealing with the binocular frames we must refer briefly to the monocular glasses for short-sighted people that are shown on quite a number of shop prints.

Fig. 6. Surfacing several lenses after Marshall's modified manner in Venice. The journeyman at the right side of the drawing is working them

We do not wish to suggest that there were in England no binocular spectacles with negative lenses; the Dunscombe Collection proves that such spectacles existed, but we must suppose that by far the greater number of the myopes preferred single glasses, especially if they belonged to the more refined classes. If there is a special commodity which occurs in nearly every spectacle advertisement it is "concave glasses in horn boxes for short-sighted persons." In order to understand this custom, we must go back to the scene described by Shakespeare (7), pp. 182, 183), where the courtier used a perspective glass, evidently a monocular glass with a handle. This seems to have been quite the rule during the Renaissance, probably because the pairs of spectacles in horn or leather frames either could only be fixed indifferently on the nose (firmly enough for writing and reading but not sufficiently well for walking about) or if more firmly they had an uncouth appearance. Thus the custom arose for ametropic courtiers to use perspective glasses exclusively

and, so to speak, by stealth. The country where, as far as we know, this custom did not prevail was Spain, and we may refer to a previous paper ((6), p. 53 and Ref. 15) to furnish evidence for the objection on the French side to the Spanish custom as being contrary to the society rules developed during the Renaissance. This Renaissance custom seems to have been consistently observed in England during the whole of the 18th century: myopic people in good society seem to have used exclusively these concaves in horn boxes in company: they could be taken out stealthily, used, and easily put back again.

About the beginning of this period, during the last years of the 17th century, the old form of horn mounting was abandoned for a leather mount. As we hope to show in our second paper, this innovation met with a hot resistance from the older freemen, but afterwards the Court altered its opinion and declared the leather frame lawful.

It may be useful here to refer to a paper (5) where the great authority A. v. Pflugk has collected together all that is known about this method of framing spectacle glasses. The earlier specimens belong without exception to the factories in the South German Free Towns. They may be dated back to the end of the 15th century but were also widely used during the 16th, to which period many well preserved pieces in modern collections are to be ascribed. This is in complete accord with the testimony of contemporary descriptions in the papers of the Nürnberg Spectacle Makers' Company and elsewhere. In South Germany this form of mounting was soon to be superseded by the metal (wire) frame, but we know that the leather frames are also mentioned in the Paris Charter (1581) and specially recommended by B. Daza de Valdes (1623) as being very agreeable to wear.

It is impossible to say in what way the leather frames were brought to England, but there is no doubt as to their manufacture here towards the end of the 17th century. In J. Marshall's already mentioned shop print (*c.* 1694) we find the sentence: "He also makes very neat Leather Frames for Spectacles, which are not subject to break as Horn or Tortois Shell," and in another shop print, probably a little later, he states: "He was the first Maker of Neats-Leather Frames for Spectacles: they being the most serviceable of any other yet made." He evidently esteems them as highly as B. Daza de Valdes did more than 70 years before.

In the same shop print he mentioned with regard to the older kind of spectacles: "I have contriv'd a pair to lie in a little Room, and to serve for a Reading Glass also." The meaning of this sentence is evidently that the pair of spectacles may temporarily serve as a reading glass when the glasses are placed one above the other.

In this instance there is no real optical invention, as the riveted spectacles always allowed such a use, which is often very convenient, but it is very probable that J. Marshall had brought about this object by some different mechanical contrivance of the frame. At the bottom of his beautiful shop print, which was drawn by B. Lens and executed by J. Sturt (both very famous artists of that time), we find some small spectacle cases, but unfortunately we cannot draw any conclusion as to the mounting of the spectacles contained therein.

It is possible that J. Swift ((12), Letters XI, XV) may have seen such a specimen,

as he mentions on 22nd December, 1710, that he bought a pair of spectacles for two shillings at Ludgate; this might have been in Marshall's shop, and he may have thought of the same place when he speaks some time afterwards of his going to buy the hinged spectacles.

The London Artisans acknowledged as Leading Spectacle Opticians

These methods of spectacle manufacture seem to have subsisted for some time; we may venture to say this as no alterations appear in the shop prints issued by the new house of G. Willdey and T. Brandreth, the competition of which was noticed even by opticians of older reputation. As far as we know, it is not until the year 1728 that E. Scarlett published a description of a spectacle invention of the highest order which is of considerable importance even at the present day, viz. the temple spectacles (Fig. 7). The first notice we have of these new contrivances is taken from E. Scarlett's trilingual shop print of the Court Collection and published in a recent paper(1). As some uncertainty has been expressed ((6), p. 62) with regard to this point, we must now revert to it, the more so as our present knowledge is farther advanced. We cannot doubt ((6), p. 52) that towards the end of the 16th century the Spanish way of fastening bow spectacles by means of threads wound behind the ears was at that time the best means for securing a pair of spectacles to the head. We may further point to the ready acceptance of this idea by Mongolian spectacle wearers, as this custom was introduced into those regions by Spanish-Italian Jesuits. It may be that, according to Daza de Valdes ((6), p. 53), some experiments had been made in Spain to fasten a pair of spectacles behind the ears by means of rigid (? metallic) parts, but the corroboration by P. Pansier's testimony mentioned on the same page(6) does not exist. Prof. A. v. Pflugk has recently been told that the old drawing of the Spaniard wearing ear spectacles cannot be found in the Peiresc Collection. It is therefore rather doubtful to us now whether Daza's ear spectacles with rigid sides had anything like an extensive use at that time: we are now more inclined to consider it as a sound idea which had been abandoned when it was found to be unappreciated.

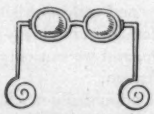

Fig. 7. Scarlett's temple spectacles of about 1728; after M. v. Rohr's reproduction of a part of a shop print in the Court Collection

When E. Scarlett's invention came out there was no proposal to fasten the sides behind the ears, as that was not feasible in consequence of the very elaborate headdress worn then and for a long period afterwards. These English spectacles were fastened at the temples and must be designated temple spectacles; we do not know of any evidence that the temple spectacles were developed from the old Spanish arrangement. They were adopted as the "English form" very soon in France, Germany, and even Spain, where in 1763 we know of illustrations of the different forms of eye-glasses then in use. These illustrations, with a printed explanation by P. Minguet, show side by side the old national thread spectacles

and the English temple spectacles without even hinting that the one might have been developed from the other.

It seems to us that with this invention of E. Scarlett the London spectacle makers reached a very high and universally acknowledged standard; the glasses sold by the best masters had had for a long time already a deservedly high reputation, but now the problem of how to attach the frame to the head of the wearer and to detach it easily was solved, a solution which had been sought after from the very invention of spectacles, i.e. for more than 400 years.

We hope to show in our second paper on the Court Collection that about this time, probably in the second quarter of the 18th century, a great alteration occurred in the status of the Company. Their members ceased to be more or less equal, as intended by the old laws; the able master craftsman obtained a decided supremacy and each optician tried with greater or smaller success to fit spectacles to his customers individually; the time of the master artisan had come for the spectacle trade, and we can only admire the growth of the ability and the success of these craftsmen.

Undoubtedly much more knowledge of the old spectacles is wanted and a large field is still open to the industry of collectors. The old spectacles in whole leather mountings seem to have disappeared rather quickly from general use and, as far as we know, no English specimen of this kind has been saved. They may have subsisted with some master makers until about the middle of the 18th century, when the focal length was marked on the frame to facilitate fitting, as expressly stated in advertisements by M. Richardson and O. Combs. It is probable that this kind of marking was soon supplanted by numbers scratched on the glasses themselves. This evolution was the more necessary as the leather bow was done away with by at least some of the English masters, and there was no room left on the frame.

Later on in different trade lists and catalogues of various makers we find mention of nose spectacles in horn and steel at the low prices of 1*s.* and 1*s.* 6*d.*

As we are now going to develop a theory of our own about the outward form of these spectacles, it is necessary to state most unmistakably the facts, so that the reader may clearly distinguish between facts and inferences.

When working at the catalogues of the middle of the 18th century* and regretting that no nose spectacles in horn and steel were known to us, one of us remembered that there were in the Jena Collection some pairs of nose spectacles (apparently of horn and steel) by unknown makers (Fig. 8). Prof. R. Greeff had bought them from Mme Heymann in Paris, but no detailed knowledge was at that time connected with them. Studying these spectacles afterwards with the help of photographs, we saw that in some instances the part where the steel spring was riveted to each of the rims had the same beak-like form as is found in No. 250

* It is only right to remind the reader that the historical value of such pieces of the Jena Collection as are represented in Figs. 4, 8, and 11 was only found out under the impulse given by Mr Court. As already mentioned, the light thrown on the 18th century spectacles by the printed specimens of his Collection was necessary in order to estimate correctly the importance of those old spectacles: without that they would have continued to lie useless and undervalued on the boards of the Jena Collection.—M. v. R.

of the Dunscombe Collection (Fig. 9) which consists of shrunken leather rims without glasses and riveted to a steel spring. The best preserved specimen in Jena appeared to have "20 m" scratched on the margins of the glasses, but we are now

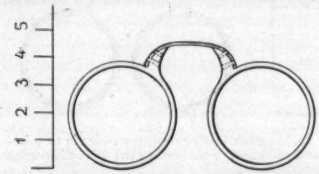

Fig. 8. A pair of spectacles apparently in horn and steel, really in leather and steel; from the Jena Collection

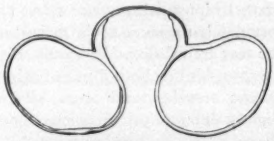

Fig. 9. Reproduction in full size of a pair of spectacles in the Dunscombe Collection in the Science Museum

of opinion that this pair was of English manufacture and "20 m" ought to read "20 in," denoting the radius of the tool employed. If this conclusion is allowed, it would seem that one of the means of making cheap nose spectacles in horn (or leather) and steel consisted in cutting out the rims with a beak-like addition in order to allow room for the two rivets or bolts*. It seems, however, that such a beak-like addition to the rim was not the only method of making cheap leather (or horn) and steel spectacles about the middle of the 18th century.

Fig. 10. Old (? English) spectacles of leather and steel in a Dresden Collection; after Prof. A. v. Pflugk (5)

A short time ago Prof. A. v. Pflugk published an account of a pair of leather spectacles with a steel spring riveted to the rims in a different, very dainty manner; he considered them as being probably of English origin (Fig. 10). We think his supposition very acceptable, as there are similar pieces with hardened leather rims fastened in the same way among the Jena spectacles from Mme Heymann (Fig. 11) and as we have other (folding) spectacles with tortoiseshell rims (evidently of English

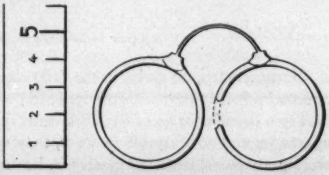

Fig. 11. (? English) nose spectacles in prepared leather and steel (damaged); from the Jena Collection

* We were at first convinced that we had before us a specimen of the nose spectacles in horn and steel, so exactly like horn was the exterior of the rims. In consequence, however, of Thomin's remark of 1746, we tried to find out whether we were not in possession of the older form of nose spectacles in steel and prepared leather. We are indebted to the courtesy of Prof. A. Köhler, who, by observing a slice of 20 $m\mu$ thickness under the microscope, identified the material as being prepared leather. We do not know how long after 1746 the leather rims were replaced by horn rims. As to the outward appearance, this change was certainly not noticeable to the general public.

origin) proving the application of the same technical means (Fig. 12). It is in the best harmony with these facts that we find an apparently similar mounting for folding spectacles on a shop print (Fig. 13) in the Court Collection. The pair of spectacles is surrounded by a pretty Chippendale ornament, but unfortunately the name of the maker and the text are missing. We do not think it impossible that both forms of mount existed together and were sold at slightly different prices, as mentioned above.

Fig. 12. English folding nose spectacles in tortoiseshell and silver, presented to the Jena Collection by Mr Court

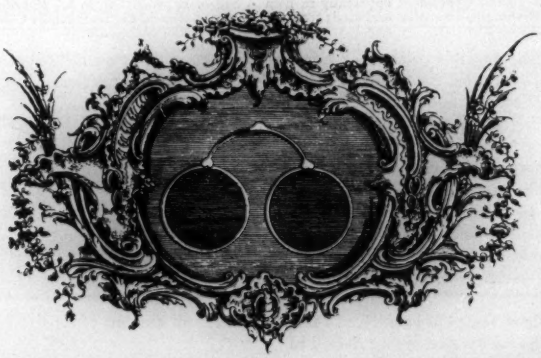

Fig. 13. Reproduction of the head of a shop print with Chippendale ornament surrounding a pair of folding spectacles (about 1750)

Summing up, we arrive at the following deductions. It is possible that the nose spectacles (of unknown form) mounted wholly in leather disappeared during the first two decades or so of the 18th century. Although less breakable than the split spectacles and comfortable to wear, they were rather clumsy of appearance. They were perhaps replaced by glasses in leather rims riveted to a steel spring. As far as we know, this was the first instance of a spectacle mounting made of two quite different materials, and we think this an invention quite as important as that of the temple spectacles. There are several specimens extant, each type designed to be worn in a special way. In the Dunscombe Collection at the Science Museum there is one with beak-like parts, and at Dresden one with dainty metal plates for the bolts; there is also a specimen of each of these types in Jena; the Dresden specimen only is supposed to be of English origin. As we may see from M.Thomin's book (13), it is possible that the leather had to be specially prepared.

It seems that these two methods for riveting were shortly afterwards applied to horn rims, for nose spectacles in horn and steel were mentioned in different advertisements and catalogues of London makers: as the horn bow had been replaced by the steel spring, the danger of breakage was diminished and the rims could be tastefully made of tortoiseshell if desired.

Specimens of both kinds in hardened leather are extant in the Jena Collection, but their English origin is only supposed. For the first more simple way we must refer to the corresponding beak-like parts in the Dunscombe specimen and the inch-measure on the glasses; for the second more refined way we can point to corresponding English pieces with tortoiseshell rims. A remarkably pretty specimen has just been secured for the Court Collection; it is a pair of folding spectacles in silver and tortoiseshell with the horn margins of Martin's visual glasses. They fit into a small silver box marked P C & S.

We may at the same time remark that the French authors dealing with the same subject (J. Rouyer in the first place, but also Mme Heymann) do not mention nose spectacles of this description, so that the probability seems to be that our view is the correct one. But there is also the positive testimony(13) of the well-known French maker Thomin in 1746 (see also (5), p. 9) that the nose spectacles consisting of prepared leather or tortoiseshell rims and metallic springs were originally made in England. The only gap left concerns the exterior of the cheap forms (in horn and steel); perhaps some contemporaneous picture or drawing will be found and allow this to be filled.

The spectacle factories of the German Free Towns need not be considered in this connection, as in the middle of the 18th century wire rims seem to have prevailed there exclusively for nose spectacles.

We expressly wish to state the problem as it stands to-day in order to instigate historical research in this direction. Some time later we may perhaps know whether we are giving to the old English masters only their due, or whether we are over-rating their faculties and ascribing to them foreign achievements.

On Scarlett's shop print of about 1728 we find at the bottom an oval-shaped lens in a peculiar mounting, and there exists one such specimen by this optician; it has been lent to the Science Museum by Mr Court. There is hardly any doubt but that it is a reading glass for the use of both eyes; the oval form of the margin was rather popular at that time. But we have not been able to account for the different movements and adjustments allowed by the mount. We should not wonder if some of the heavy candlesticks of that period were made with a narrow and deep cavity in order to receive the stem of the mounting. In this case the lens could be easily adjusted with regard to height and inclination to allow a convenient view of printed matter or other rather small objects. We learn that in 1686 ((6), Ref. 30) J. Zahn described the use of such oval lenses held by hand above small print and fine anatomical objects. Obviously contrivances known at that time in Würzburg were also well known in London; Scarlett may have wished to improve the facility of using this instrument.

With regard to the surfacing of lenses according to Marshall's invention, we

learn from the two representations in Figs. 14 and 15 that the grinding movement was exclusively given to the tool by the hand of the artisan, the lens or the block

Fig. 14. Ornamental etching of the middle of the 18th century showing the grinding of lenses; after the original in the Court Collection

Fig. 15. J. Ayscough as a lens grinder; after a shop print from the Court Collection

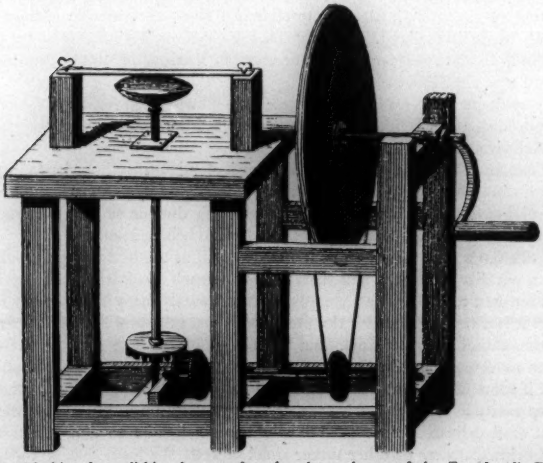

Fig. 16. Machine for polishing lenses; after the plate volumes of the *Encyclopédie Française*, said to have been published between 1761 and 1763

of lenses being stationary. We do not know as yet at what time it became the practice to give a rotation to the lens or the block of lenses as well. The earliest representation known to us of an optical workroom containing a machine for giving

this rotatory movement is taken from the plate volumes of the *Encyclopédie Française* (Fig. 16). As these plates are said to have been published between 1761 and 1763, these contrivances must have been in use in Paris by that time. This contrivance was worked by an assistant who turned the handle. A much smaller working table (Fig. 17), where the optician himself set the lens in motion with the left hand and ground the surface with the right hand has been described in (2). It belongs to the Jena Collection and may be dated back to the end of the 18th century, as it had been used probably by E. Unkel's predecessor H. J. Bücking in Marburg. Evidently only single and comparatively small lenses (spectacle lenses) could be ground on it; block work was not known to this optician.

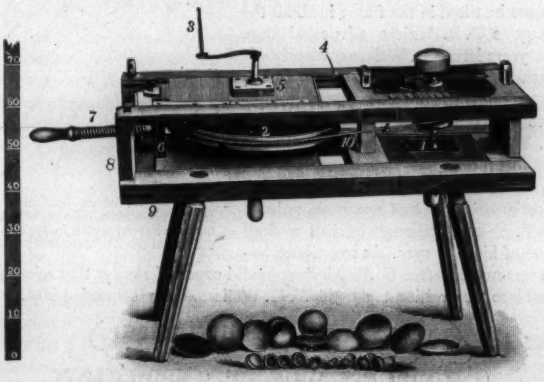

Fig. 17. Grinding and polishing machine of German manufacture towards the end of the 18th century; lent to the Jena Collection by Mr Unkel

This still incomplete knowledge allows us to form a better judgment of the very remarkable time when so many English patents for spectacles were taken out. These patents have already been dealt with ((6), pp. 63–5), and there is not much that can be added. An interesting portrait of a Dutch landscape painter (Fig. 18) gives us the evidence that A. Smith's invention ((6), Ref. 71) was really used in order to furnish presbyopic people with a substitute for bifocal spectacles.

No more accurate knowledge is forthcoming as to the date of the first pair of bifocals since B. Franklin's publication in 1784–5, and we should like to direct the attention of all collectors to this interesting point. More evidence would be welcome also with regard to B. Martin's visual spectacles; although G. Adams in his essay on vision rather deprecated Martin's invention, we find in a price list of his (probably about 1777) the following item: "Visual glasses or Spectacles with a contracted aperture." And later still we find visual glasses as nose spectacles advertised by Gregory L. Wright, who came from Mr Martin's in Fleet Street.

As some time ago ((9), pp. 121–2) some remarks were published in these *Transactions* with reference to the Jones-Wollaston controversy, we shall refrain from going again more deeply into this question here, but we might cite a very curious article (14) as appertaining to this question. E. Walker objects to the periscopic form because he has evidently astigmatic eyes and must look obliquely through his spectacles in order to correct his astigmatism. He recommends that the glasses be tilted in the frame in about the same way as G. B. Amici (8) advocated more than 30 years later. E. Walker evidently did not know that he was using the same means of correcting his eye defect as that communicated to T. Young by W. Cary four years earlier. We see from this paper how difficult it was at that time to defend the new periscopic glasses against such a criticism, as the defect of an astigmatic eye had not been pointed out by T. Young, although he had noticed it in one of his own eyes. As mentioned before, it was not till after G. B. Airy's splendid paper of 1825–7 that scientific men were put into the position to defend W. H. Wollaston's well-founded idea.

Fig. 18. The Dutch landscape painter Jelderhuis with a pair of bifocal spectacles; after A. Smith in 1791. Observe the use of the double-jointed sides

Periscopic Spectacles
on a New Principle made by
CHARLES WEST, OPTICIAN,
West Gallery of Lincolns Inn 2
at his Manufactory N°5, Cursitor Street, Chancery Lane, London.

It must have been remarked by persons who are accustomed to use Spectacles, that no objects appear distinct, which are not seen nearly through the centre of the glasses, and that the want of distinctness is greater in proportion as the direction of the sight is more inclined to their surface, as is represented by the line F O, in which F is the place of the eye.

Conformably to this new principle, it is found, that if a Glass be made according to the Section here represented, in which the exterior surface has a greater degree of curvature than the interior, it has the best form for long sighted persons

The form for short sighted persons must be as is shown in the annexed figure, where the exterior surface has a less degree of curvature than the interior.

Fig. 19. Full size reproduction of Charles West's shop print, belonging to Mr Court

The opticians of that time had evidently no adequate insight into the properties of the Wollaston form. Not to mention W. Jones's stubborn antagonism, we must

conclude this from P. Dollond's aversion to bring out the periscopic glasses with deep curvatures. He never contradicted, as far as we know, Jones's statement that Dollond's glasses were nearly plano-convex. Charles West's print (Fig. 19) relating to periscopic spectacles also gives some insight into the reception of this form in England. The forms of the lenses with the inclined secondary axis are evidently taken from Wollaston's paper of the year 1804, and we may suppose that the cards were distributed when Wollaston's patent had become void after 1818.

Conclusion and Outlook on the Future

There must have been some remarkable alterations in the spectacle trade about this time, although we are not able to give many details.

Dr Kitchiner's book (3) published in 1824 and 1826 probably gives us the best information obtainable from any man outside the trade. It is very remarkable that this trustworthy witness does not say anything about the nose spectacles; temple spectacles in hammered silver and steel seem to have replaced all other forms; tortoiseshell spectacles are not recommended as they are too breakable and often of an unsuitable colour. The beautiful folding spectacles for the nose and the useful cheap nose spectacles in horn (? leather) and steel seem to have vanished from the market, and we can accept such a development the more readily as we cannot otherwise explain the difficulty of introducing the "pince-nez" to the customers in the period after 1840. The old English nose spectacles mentioned above were decidedly more serviceable and much daintier than the first forms of the "pince-nez."

We are not able as yet to give the reason for this tendency, but there now occurred a great setback in the development of the London spectacle maker. Even if we remember the undoubted skill of metropolitan artisans like R. Bretell Bate or G. R. Elkington in bringing out new and effective forms of eye-glasses, it does not seem as if the London opticians were aware of the necessity of providing for the wants of the public in general and of customers with small means. We must mention that, on the Continent at least, the English steel frame so well known towards the end of the 18th century was gradually replaced by the French frame coming from Morez, or by home-made frames, and soon after by huge numbers of folding glasses of Paris manufacture (*face à main brisée*).

As to the spectacle glasses, we conclude from (11) that an attempt to bring out cheap machine-made glasses was violently opposed by reasons that we consider to-day as very doubtful if applied to spectacle glasses, and, as far as we know, spectacle glasses continued to be made in rather restricted quantities in London. But in the meantime the as yet small factory of A. and E. Duncker in Rathenow grew rapidly, and although their methods were by the fourth decade out of date and not very effective, it could not be difficult (was not, in fact) to improve them. In this way the Rathenow factory began with decided advantage to induce the professional men, not only in Germany but in the northern and eastern parts of

the Continent as well, to buy from this reliable factory ready-made spectacle glasses, if not spectacles complete, and to develop from spectacle makers to spectacle vendors first, and afterwards to spectacle fitters. Some decades later the great American factories were founded, and, as they worked in the same direction, the modern system prevailed more and more with the professional men. In this way the master artisans, who had done such splendid services in the 17th and 18th centuries, were for spectacle glasses replaced by the workmen of large well-directed factories (Πάντα ῥεῖ).

To-day we can only indicate this inevitable alteration which has gradually taken place from the fifth decade onwards; as yet a true description of the different steps and stages of this highly important change cannot be given with the knowledge at our disposal.

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(14) WALKER, E. "On spectacles; particularly the periscopic" (19. iii. 1804), *Nichols. Journ.* 1804 (291–4), 2 Figs. [18.]

DISCUSSION

Mr R. S. Whipple: We are all much indebted to Mr Court and Prof. von Rohr for this interesting paper. We all admire the energy with which Prof. von Rohr has collated the facts which have been so industriously collected by Mr Court. We are just beginning to realise what a debt the community owes to Mr Court for the patient way he has collected the old instruments and books from which the history of the English optical industry is being gathered.

We shall all look forward with much interest to the further papers we are promised on the Court Collection.

Mr D. Baxandall: With reference to the old pair of leather spectacles belonging to the Dunscombe collection in the Science Museum, I am sure the authors of this interesting paper will be glad to know that the leather is riveted to the metal exactly as indicated in the illustration of the Jena example.

There are a few points in the paper which one would like to discuss, but as further information will probably be available in the other papers which the authors have in preparation, perhaps a more suitable opportunity for discussion may be provided later.

THE RELATIONS BETWEEN FIELD ILLUMINATION AND THE OPTIMUM VISUAL FIELD FOR OBSERVATIONAL INSTRUMENTS

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(Research Student)

MS. received, 26*th September*, 1928. *Read and discussed*, 8*th November*, 1928.

ABSTRACT. The paper describes some experiments based on the application of the results of recent studies on "spatial induction" in vision to determine the conditions governing the optimum size of visual field under certain conditions. The results have a bearing on recent efforts greatly to enlarge the fields of view of binoculars, indicating that small fields are better under certain conditions.

Introduction

Great efforts have recently been devoted to the extension of the visual field in prism binoculars. There can be no doubt that a large field generally inspires ease and confidence; the physiological facts of scotopic vision call for the largest attainable field as well as for a necessary degree of magnification. It is well known, however, that photopic vision has characteristic differences from the scotopic stage, and the enquiry may well be made as to whether the widest possible field is the best under all conditions.

Previous experience of the general class of phenomena known as "spatial induction" and the work of many observers*, mentioning only Cobb, Ives, Nutting, and Allen amongst many, had indicated that there is a very general dependence of the sensitiveness of the fovea (to various forms of visual impression) on the state of illumination or adaptation of the surrounding parts of the retina. Also, for example, the work of Emerson and Martin† with monochromatic stimuli had shown that the contrast sensibility of the fovea could generally be increased by surrounding the matching field, used to measure the contrast, by a field of the same colour and of suitably low intensity. As the brightness of the surround

* A digest of the literature on this topic will be found in "Report on Illumination and Visual Capacities" by R. J. Lythgoe (Medical Research Council), published by H.M. Stationery Office, 1926.

† Emerson and Martin, *Proc. Roy. Soc.* A **108** 1925 (488).

increased, an optimum foveal sensitiveness was reached, thereafter diminishing until an over-bright surround resulted in glare and practically a total absence of foveal discrimination. Some of the results of various observers concerning the effect of lateral illumination on visual acuity are discussed by Parsons*. The experiments just mentioned supported the likely idea that the most serious drawbacks of a large field would be apparent when a considerable difference existed in the brightness of the retinal image at the central and peripheral parts of the retina.

Naturally there is an infinitude of conditions of observation in the ordinary use of telescopes, but in order to gain concrete ideas some more or less representative set of conditions must be examined; take for example the observations of flag signals in military operations. These were often made with white flags, so the signaller would take care to select a dark background, a building or clump of trees. If the day is fine it often chances that the general brightness level of the field is much higher than the image of the dark "background object" which will occupy, perhaps, a small part of the centre of the field. A ship, dark on a bright sea, offers another typical instance of such a contrast in brightness between the central and surrounding parts of the field. The preliminary laboratory experiments were devised with such conditions in mind.

General Method of Experiment

As the general physiological and psychological conditions of an observer are not under precise control at any time, and as these factors influence retinal sensitiveness, a statistical method of experiment was employed.

The eye observed the objects by means of a telescope, the direction of vision being fixed towards a small central aperture seen in the illuminated field. After a definite period of this fixity of vision a test object, *of such brightness that it was only distinguishable with difficulty*, was exposed momentarily at this central aperture. After a definite interval another object was exposed which had to be recognised if possible; the observer recorded the appearances of a number of these exposures. The *size* only of the surround field was then changed and the observations systematically repeated, the grouping of the observations being so chosen to eliminate in the final result, as far as possible, the "education" and "fatigue" effects which are always to be encountered in experiments of such a character.

By checking the observer's record with the actual series of objects exposed, the comparative accuracy when using a large field and a small field could be estimated from the number of errors and missed observations.

Experimental Apparatus

The three essential parts comprised the telescope, the device for providing the sensitising (surround) field and varying its illumination, and the device for exposure of the test object in the centre of the sensitising field. The references are to Fig. 1.

* Parsons, *Roy. Lond. Ophth. Hosp. Reports*, 19 (2) 1914 (376).

The telescope T consisted of a short-focus achromatic object glass and a Ramsden eyepiece, the whole magnification being 2·5. A slot was cut in the telescope tube at the focal plane of the eyepiece, and the size of field could thus be controlled by the insertion of brass diaphragms. Focussing was effected by movement of the object glass.

In earlier experiments one unit of a pair of prism binoculars was furnished with a small diaphragm to limit the field of view. Either unit could be brought into action by the operation of a slide.

A concave spherical mirror M, with a small central aperture 0·4 cm. in diameter, reflected light from an opal glass lamp L_1 into the telescope; thus, utilising the "Maxwellian view," the whole of the visual field was filled with light. The intensity of the sensitising field was varied by means of an annular gelatine wedge placed immediately in front of the aperture in the housing containing the lamp L_1. In earlier experiments the mirror was represented by a screen of white cardboard with a central aperture, and illuminated by a suitably placed opal glass lamp.

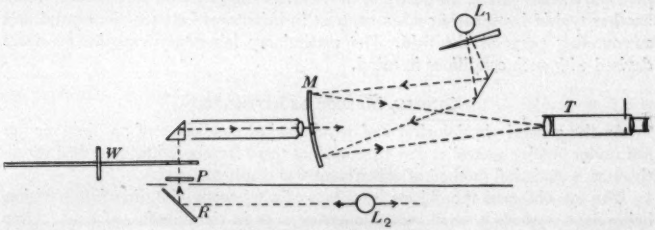

Fig. 1. Diagram of apparatus

The test objects at first used were black letters on white cards. These could be introduced at P, and their images were projected into the aperture of the screen or mirror; in later experiments the cards were replaced by transparencies exhibiting a black semicircular object which could be shown with the convexity "up" or "down," or a group of five parallel lines which could be shown either "vertical" or "horizontal." The rotating disc wheel W contained a peripheral slot which exposed the object for a duration of 0·1 sec. once in every 4 secs. In earlier experiments made by two observers, M. and J., the object was changed arbitrarily by hand by an assistant between each exposure and the next. In later experiments made by R. without an assistant a wooden disc, 10 inches in diameter and $\frac{5}{8}$ inch thick, had 20 notches cut in the periphery in which 20 "line type" transparencies could be placed in any order after "shuffling"; thus the successive objects could be brought into the exposure position consecutively on rotation of the wooden disc. Both discs were mounted on brass spindles and, by a system of gearing, the speed of rotation of the wooden disc was maintained at 1/20 that of the wheel, thus giving an automatic change of object. The transparency was illuminated from

below by a magnesium carbonate reflector R, illuminated in its turn by an opal glass electric lamp L_2, mounted on a slide in order to obtain an adjustable intensity.

First Experiments

As mentioned above, the two members of a pair of binoculars were employed at first for obtaining a rapid change in the size of field; in one unit the field was cut down to about 20 degrees as against the full field of about 50 degrees in the other. The assistant changed the test object between each exposure, the observer read it aloud and the former recorded the result, right or wrong or missed. The time table and grouping of observations was as follows:

Time	
Zero	Observer looks into large field
1 minute	Twenty observations begin (occupying 100 seconds). Set 1
3 minutes	Change to small field
4 ,,	Twenty observations with small field. Set 2
6 ,,	Change to large field
7 ,,	Twenty observations with large field. Set 3

and so on for six sets. It was hoped in this way that some of the various factors of "practice" and "fatigue," etc. would be sufficiently eliminated in the mean of the results.

The exit pupil of the binocular possessed a diameter of 4 mm. which would control the pupil effective in vision under the conditions of the experiment. Independent measurements show that the right eye exposed to such a limited field, of brightness 20 foot-candles, under laboratory conditions would possess a diameter of over 5 mm. The white cardboard screen was first used to illuminate the field. The central aperture appeared dark except when a letter flashed into view, and the brightness of the latter image was adjusted so that the letter was barely readable.

Under these conditions the preliminary experiments had shown that generally all observers failed much more frequently to read the letter with the large field than with the small. The range of field brightness varied from about 2 to 25 foot-candles.

Other preliminary experiments were arranged so that the central aperture remained at the same brightness as the surrounding field except when the letter appeared. Under these conditions the advantage of the smaller field was no longer manifest, and observers made approximately an equal number of errors with both large and small fields.

When systematic observations were begun it was found that in the vast majority of cases the observer either named the object correctly or else failed completely to recognise it with sufficient certainty to venture a call. Thus in many sets of 120 observations there might be only about two mistakes, but perhaps up to 60 or so missed observations. Hence, in order to give the simplest presentation of the results, the mistakes and misses are added to give the number of "failures." In Table I the first systematic results made by L. C. M. and B. K. J. are given. The sliding binocular optical device was employed to vary the field; the object,

a small semicircle which could be shown with the flat edge up or down, was changed by hand. Precautions were taken so that the observer could not tell in any way whether the object was being changed or not. The numbers of failures in 60 observations are given in Table I. The central field subtended about 2·5 degrees.

Table I

Number of failures in 60 observations

Field brightness in equivalent foot-candles	Observer L. C. M.		Observer B. K. J.	
	Field diameter		Field diameter	
	50°	20°	50°	20°
100	26	11	37	7
75	23	15	27	11
50	17	18	28	8
45	10	9	16	13
30	28	4	33	7
20	15	5	29	17
10	27	13	11	15
5	25	25	28	31
1	4	12	11	32
0·25	14	26	10	30
0·10	4	8	13	11
0·02	17	40	25	38

Except for a few discordant results the general trend of the observations is quite definite. With the brighter fields, over 5 to 10 foot-candles, advantage is obtained by diminishing the size of the large bright field surrounding the central aperture into which the letter flashes; on the other hand, the effect is reversed at a low brightness, and advantage is obtained by enlarging the field. In order to obtain independent confirmation of these results a new series of tests was undertaken in which the size of the field could be controlled by the use of a series of stops which could be inserted in the focal plane of the single telescope, thus giving fields of 11, 20, 28, 50, and 64 degrees. The objects were changed automatically as described above, so that the tests could be made by one observer. Twenty shuffled test objects were inserted haphazardly in the notches of the wooden disc; each notch was numbered so that the commencement of the observations could begin with any number, the corresponding type of test object and the succession thence being, of course, unknown to the observer.

The eye was adapted to the field for 1 minute in each case before commencing a series of observations; the time table given above was not followed, but the size of the field was changed between each set of observations so that the range of sizes was covered in five sets, occupying about 20 minutes. The discrepancies in the observations were then tabulated by checking them against the correct types. Ten complete groups of observations were made, in all, for each field brightness by the observer T. C. R., and his results are given in Table II. The apparent subtense of the central field was about 5 degrees.

The results below confirm those of the earlier experiments; for a brightness above about 10 foot-candles the small field appears the better, but below this level the large field confers some advantage.

It was mentioned that the brightness of the central image was adjusted before beginning a set of observations so that it was recognisable only with difficulty under the brief duration of the flash; the object was dark on a light ground, and in

Table II

Observer T. C. R. Number of failures in 200 observations

Brightness of sensitising field in foot-candles	Size of outer field				
	11°	20°	28°	50°	64°
150	45	37	61	79	80
50	55	65	69	71	80
20	47	61	75	97	120
10	55	47	58	55	66
3·5	94	83	57	78	73
1·5	108	98	84	102	90
0·1	74	89	77	72	50
0·01	125	100	92	67	86

the conditions of one experiment it was found that the "ground" within the central field had a brightness of 5 foot-candles. This was approximately the brightness level at which the change-over from one condition to the other occurred, i.e. advantage from a smaller or larger field.

In connection with this interesting observation, it may be noted that Cobb* describes a critical point when the brightness of the test objects and the surrounds are the same; at this point the percentage limen of contrast is a minimum. Probably there is nothing fundamental about the particular brightness at which the change-over occurs.

In order to present the results of Table II graphically a term "discrimination error" can be defined by the equation

$$\text{discrimination error} = \delta = KE,$$

where E is the number of failures, and where the constant K is so chosen for each set of results for one field brightness that KE is unity for the surround field of 20 degrees. In Fig. 2 the values of δ are plotted against the diametral subtense of the surround. Though the results for 50 foot-candles are somewhat discordant and the slopes of the "curves" are not always consistent, especially between 10 and 20 foot-candles, the difficulty of securing perfectly consistent results in "statistical" experiments when only a limited number of observations is possible would not justify any conclusions based on the irregularities. The general trend of the curves is quite evident. A slope upwards to the right shows a greater tendency to error with a larger field; this is, in general, most pronounced at a high field brightness.

* Cobb, *Journ. Exper. Psych.* 1 1916 (419, 540).

There is one point in connection with the above results by R. which must be mentioned: the effective exit pupil controlling the brightness of the retinal image of the surround was of the order of 2 mm., while that controlling the brightness of the central image was the pupil of the eye, since the ordinary telescope exit pupil had a diameter of 10 mm.

Suppose the surround field to be enlarged; then the total stimulation of the retina would be increased and the pupil of the eye might be expected to shrink somewhat. Hence the brightness of the central image relatively to that of the surround would be diminished and an increased number of errors might be expected on this account. The general effect of this would be to confer advantage on the smaller fields at all brightnesses, but mostly when the field brightness is high. It is to be remembered, however, that this effect was not operative in the

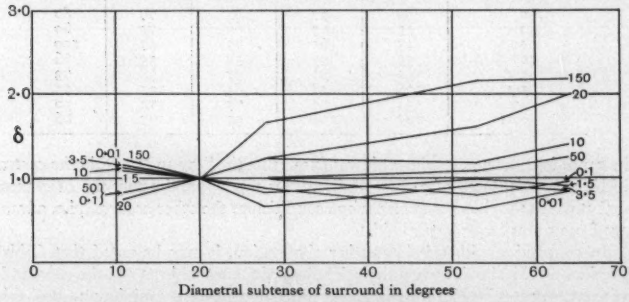

Fig. 2. Relation between discrimination error and angular subtense of the surround for various levels of brightness

earlier experiments, and the effect on the pupillary diameter of a change in the size of field is only a very small one when the diameter is over 10 to 15 degrees. French's experiments* showed that "it is the macula lutea and a comparatively limited portion of the retina round it that control the variations of the pupil diameter." In particular French showed that the sensitiveness of the iris reflexes reach a minimum at an angular distance of about 25 degrees from the fovea. Hence the explanation of the phenomena of the experiments by R. now described can hardly be attributed to the variations of the iris.

Experiments with coloured stimuli were also made by T. C. R. Suitable Wratten filters were used to obtain sufficiently monochromatic light, the wedge being re-calibrated as required. Sets of observations were made for red, green, and blue lights and are shown in Table III. The figures tabulated are, as before, the numbers of failures in 200 observations. B is the brightness of the surround in foot-candles. Experiments were made for fields of 20 and 50 degrees only.

* French, *Trans. Opt. Soc.* **20** 1918–19 (229).

The results are exhibited graphically in Fig. 3, the relative discrimination error for 50 degrees as compared with 20 degrees being plotted against surround brightness in foot-candles for each of the colours red, green, and blue. An increased inductive effect for the shorter wave-lengths is apparently indicated.

Field Experiments

A pair of binoculars was fitted by Messrs Ross, Ltd., with iris diaphragms in the focal planes of the eyepieces; by this means the field of view could be varied between about 5 and 45 degrees as desired. These binoculars have been used on several occasions by both trained and untrained observers, and the agreement of opinion amongst most of these was quite definite.

For observing objects which are at the general brightness level of the surroundings, whether in strong or faint light, the larger field was unanimously preferred. In the ordinary use of binoculars, however, it is often desired to view objects (moving or stationary) which are in a comparatively dimly illuminated part of the field while the surroundings are generally bright. When facing the light this condition is very frequent; many instances need not be detailed, but one case would be an object in the shade of a tree seen in the distance when the observer faces the sun. For conditions of this kind, both skilled and unskilled observers agreed that the possibility of cutting down the size of the field of view was a great advantage. In order to realise this to the full the diaphragms would best be controlled simultaneously by a single milled head.

Table III

Observer T. C. R. Number of failures in 200 observations

Red			Green			Blue		
B	Failures for		*B*	Failures for		*B*	Failures for	
	20°	50°		20°	50°		20°	50°
18	46	56	17	42	73	15	25	59
13	49	48	13	44	42	12	32	54
8·5	53	47	11·5	84	80	6·7	89	88
5·0	56	46	7·5	44	53	4·5	38	31
3·5	59	64	2·5	60	51	2·0	76	71
1·3	51	37	1·3	57	51	0·8	38	29
0·15	69	69	0·15	79	43	0·15	53	28

Attempts at quantitative tests were also made by T. C. R., chiefly in dull light; the results of these confirmed the conclusions reached from previous work in the Technical Optics Laboratory.

A simple device was constructed for quantitative observations. It consisted of a 1-foot square piece of cardboard with a 2-inch square hole in the centre of it; a rotating cardboard sector upon which were pasted two test objects—a black disc and a black square; a black shutter which could be inserted between the sector and the 2-inch square hole. The assistant provided a momentary exposure of a

test object at intervals of about 5 seconds, the observer recorded the appearance of them, and, at the end of 20 exposures, the surround field was varied in size and another set of readings recorded.

Observations were made on four occasions at nightfall, and in spite of the difficulties encountered, such as discomfort of the observer and the rather rapid darkening of the surround intensity (this latter difficulty tended to lessen the range of vision), satisfactory results were obtained.

On the first occasion the binoculars were used, and at a surround intensity of roughly 0·5 foot-candle, the number of errors in 20 exposures was 12 for a large field and 16 for a small field. On the next three occasions the telescope used in the laboratory experiments was employed. The surround brightness was about 0·5 foot-candle, and the total number of errors in the sets of 120 exposures was 51 for the large field and 63 for the small field. The advantage in using a large surround field for contrast discrimination in a central object under conditions of low illumination is clearly indicated.

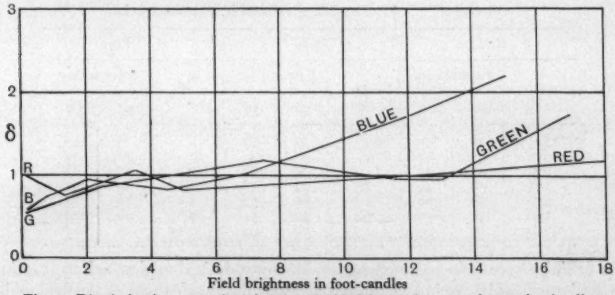

Fig. 3. Discrimination error plotted against field brightness for monochromatic stimuli, red, green, and blue

Summary of Conclusions

It has been shown that under certain conditions of vision with a telescope, when relatively dark objects must be observed in the centre of a bright field, advantage can be obtained by reducing the size or brightness of the peripheral parts of the visual image. The advantage indicated by laboratory experiments of a statistical kind has been confirmed by quantitative field tests with binoculars possessing a variable field. On the other hand, the experiments have clearly confirmed the advantage of a large field under conditions of low illumination or where the object is brighter than the surrounding field.

These results are in harmony with those expected from previous experiments on visual sensitiveness. It is not intended to discuss the physiological aspects of the results at present, but it may be pointed out that these experiments have again tended (so far as they go) to confirm the results of Emerson and Martin, who found

the shorter wave-lengths to be the more effective (for equal visual luminosity) in their effects of induction. If the peripheral parts of the field were dimmed by means of an annular yellow filter it would be probably as effective as an actual reduction in the size of the field, but the latter expedient, while interesting, will probably not commend itself to instrument-makers who may, however, feel inclined to make some experiments for themselves on binoculars with variable fields.

Our sincere thanks are due to Mr B. K. Johnson, who assisted in much of the experimental work, and to Captain T. Y. Baker, R.N., for his interest and assistance.

DISCUSSION

Comdr N. M. S. Langlands: The paper is undoubtedly of great interest and value. It would, however, have been much safer to have restricted the pupil artificially, since French's work on this point can hardly be considered to be conclusive. Cobb stated that the effect of peripheral stimulation on visual acuity is much less than on differential sensitivity. The experimental work in this paper really deals with the effect of peripheral stimulation on a momentary glimpse of the test object. It does not follow that similar results should ensue when the central object is exposed for several seconds instead of for 0·1 sec. I am inclined to believe, from the results of a series of binocular observations, that peripheral stimulation has a small or even an adverse effect on binocular resolving power, tested on a central object. This also may be true of monocular resolving power. The better appreciation of the shape of the test object may, therefore, perhaps be due simply to the increased differential sensitivity. The effect of peripheral stimulation seems to depend not only on the brightness of the surround and the central object, but on the duration of their exposures. I have certainly found that, using surrounds and central light points of the same brightness as those used by Dr Martin in his paper on differential sensitivity, the effect of the surround is never to increase but usually to lower the binocular resolving power at the centre of the field.

Capt. T. Y. Baker: I can confirm that when using a binocular in daytime it is often of great advantage to be able to cut down the total field for the purpose of observing greater detail in a small part of that field. During the summer I was able to make numerous trials of the pair of Ross binoculars to which Dr Martin refers. I found that when off the coast in a small launch I frequently had to pick up my position by bearings of a distant beacon that was not too easy to recognise owing to its similarity to another one not far from it. By cutting down the field to something only just larger than the beacon itself the task of recognising it was made much easier.

There are many occasions of a similar nature where I am sure that the possession of a pair of binoculars with adjustable field stops would be invaluable to a sailor. He has always to contend with considerable glare from the water, and the possi-

bility of cutting a great deal of this out of his field of view would be a boon. Binocular manufacturers might with advantage consider the question of putting such binoculars on the market specially for marine work.

Mr T. Smith: Observations of the type recorded in this paper are of wide interest, and I think all relevant details should as far as possible be stated. The authors give no figures for the brightness of the letter that formed the test object, but say this was adjusted so that the letter was barely readable. This presumably means that this brightness was not constant throughout the series of experiments. If the figures for the illumination of this part of the field are available I hope they will be added before the paper is printed.

Prof. Martin (partly communicated): Comdr Langland's criticism is quite correct; it would have been much more satisfactory in the second group of experiments to have restricted the pupil by reducing the aperture of the object glass. The exact bearing of the results on the retinal functions alone would have been more definite. As I have pointed out, the pupil *was* controlled in the first group.

It so happened that this source of uncertainty was overlooked in making the second group until it was too late to repeat the work in the time available. The results have, however, a bearing on the experimental problem and constitute good evidence on the grounds given in the paper. Perhaps it may be pointed out that with many types of binoculars, and under conditions of bright fields, the effective pupil in field use will not always be controlled by the instrumental exit pupil. In such a case the advantage of a variable field in observations of the type contemplated in the paper would probably be accentuated.

I quite agree that there is sufficient evidence to show that peripheral stimulation does not greatly affect the central monocular or binocular form acuity in ordinary steady vision, provided that the contrast and illumination in the central field are sufficient. In the object exposed, the contrast was very great and the object would be recognised with the greatest ease in steady vision; it would seem doubtful whether the differential sensitivity is much concerned. We are dealing with some complex time threshold function. Of course it should be understood that these experiments were quite of an exploratory and preliminary character. The disentangling of the physiological actions would need much more extended experiments.

I am glad to have Capt. Baker's corroboration of my own experience with the binocular in actual practice.

In reply to Mr Smith, the instantaneous brightness of the background for the test object, seen as it occasionally came into view, was always adjusted during the actual progress of experiments till the condition of uncertainty was reached. The actual values used from experiment to experiment were liable to such big variations with the practice factor, physical condition, and fatigue that we felt it would not be adding anything to the value of the work to try and get any consistency in the absolute results for such details. We concentrated rather on trying to find whether or not any positive variation in the visual performance could be connected with a variation of the size of the field. I quite agree that a trustworthy

and consistent record of the brightness of the flash would be interesting and valuable, but I do not think any results we could have given for this were trustworthy enough to record. Naturally a considerably higher brightness had to be used for the central field when the outer field brightness was high. Our results seemed to indicate that at about 5 foot-candles for the outer field the brightness of the central field (background) required in the experiment was the same (i.e. 5 foot-candles) and it was at this brightness level that the change-over occurred. For lower brightnesses the larger fields tended to confer some advantage, the outer field being less bright than the central during the flash.

LENSES AND EQUIPMENT FOR ULTRA-VIOLET PHOTOGRAPHY

By Col. J. WILLIAM GIFFORD, F.R.A.S.

MS. received, 6th June, 1928. *Read and discussed, 11th October*, 1928.

ABSTRACT. A description is given of the type of photographic doublet generally known as rapid rectilinear, in which (1) fluorite and quartz, (2) quartz and calcite are substituted for the ordinary crown and flint glasses. These doublets are therefore more or less transparent to the ultra-violet as well as to the visual spectrum. Corresponding lists of focal lengths for twenty-one wave-lengths are given, as well as the radii, thicknesses, etc., for construction. A cement transparent to the ultra-violet for use with these lenses is described, and photographs of the spectra transmitted by certain light filters are given.

Introduction

The object of the present paper is to describe and give data for the construction of rapid rectilinear combinations of fluorite and quartz and of quartz and calcite for the photography of objects illuminated by ultra-violet rays, and also to describe an ultra-violet cement and certain light filters for use with them.

At the outset it will be well to understand what the possibilities are with doublets of these substances. Using the same terminology as for the visual spectrum, a fluor-quartz combination is apochromatic, that is, it is possible to equalise focal lengths for three wave-lengths of the spectrum; but with quartz and calcite it is only possible to make two equal.

The rapid rectilinear or rapid symmetrical type of photographic lens is a very old and a very simple one. It will therefore be enough to say that it consists of two similar doublets, each being formed of a meniscus and a double concave element. The calculation is for parallel rays incident on or emergent from each meniscus, and their principal planes are made coincident.

Fluor-Quartz Combination

Choosing two wave-lengths at a sufficient distance apart for the equalisation of focal lengths, we shall find that the focal length for a third wave-length lying between them is automatically equalised. Let us take the lead line Λ (5609 Å.U.), the point of maximum luminosity in the visual spectrum, and wave-length 2446 Å.U., the silver line, for our purpose. Then, calculating the focal lengths, we shall find that for wave-length 4861 Å.U., the hydrogen line, the lens has practically the same focal length. And indeed several other wave-lengths require more than

three decimal places to determine any difference of focal length from the original two chosen. The values for a focal length of unity are given in Table I.

TABLE I

Wave-length	*F*	Wave-length	*F*
7066 (*B'*)	0·99915	2749	0·99869
6563 (*C*)	0·99949	2573	0·99925
5893 (*D*)	0·99998	2446	*1·00000
5609 (A)	*1·00000	2313	1·00038
5270 (*E*)	1·00016	2265	1·00154
4861 (*F*)	*1·00003	2194	1·00259
4341 (*G'*)	0·99984	2144	1·00377
3962	0·99955	2099	1·00470
3610	0·99911	2062	1·00560
3302	0·99902	2024	1·00699
3034	0·99894		

It will thus be observed that even for a wave-length of 2024 Å.U. the error for unity is less than 0·01 and that the three focal lengths have been equalised as stated. They are marked with an asterisk. The two wave-lengths originally chosen are shown in black type.

The data (radii, thicknesses, etc.) for a focal length of unity are as follows (see Fig. 1):

$$R_0 = 0{\cdot}273003 \qquad R_2 = R_4 = 0{\cdot}152449 \qquad R_8 = 0{\cdot}563006$$
$$R_8 = -R_6 \qquad R_{10} = R_{12} = -R_2 \qquad R_{14} = -R_0$$
$$t_1 = 0{\cdot}0183989 \qquad t_3 = 0 \text{ (air)} \qquad t_5 = 0{\cdot}0165590$$
$$t_9 = t_5 \qquad t_{11} = t_3 \qquad t_{13} = t_1$$
$$D \text{ (vertex to vertex)} = 0{\cdot}158724$$
$$F = 1{\cdot}0$$

These data for unity may of course be multiplied in the usual way by the focal length required.

It was found impossible entirely to remove the longitudinal spherical aberration of which there remains 0·000536. A plate $4\frac{1}{4} \times 3\frac{1}{4}$ inches is covered at full aperture when the focal length is 6 inches and the aperture 1 inch. This lens has been constructed.

QUARTZ-CALCITE COMBINATION

This is a much earlier and less perfect construction, since the focal lengths for two wave-lengths only can now be equalised. But, when it is required to photograph experimentally objects of some size illuminated by ultra-violet radiation only, it is not to be despised, since calcite costs less than fluorite. The action of such a combination was described and a rapid rectilinear doublet of focal length 10 inches covering plates $6\frac{1}{2} \times 4\frac{3}{4}$ inches was actually shown at the meeting of the British Association at Bristol in 1898, but no interest whatever was taken in the matter then or subsequently.

Spherical aberration and coma are greater than with the fluor-quartz combination and the definition is not so crisp at full aperture (1½ inches), but, using diaphragms, very useful results are forthcoming.

The values for a focal length of unity are given in Table II.

TABLE II

Wave-length	*F*	Wave-length	*F*
7066 (*B'*)	1·00345	3034	0·99290
6563 (*C*)	1·00226	2749	0·99565
5893 (*D*)	1·00075	2573	1·00002
5609 (A)	1·00002	2446	1·00649
5270 (*E*)	0·99907	*2313	1·01681
4861 (*F*)	0·99773	2265	1·02292
4341 (*G'*)	0·99596	2194	1·03409
3962	0·99449	2144	1·04515
3610	0·99340	2099	1·05762
3302	0·99255	2062	(absorption)

* The spectrum of iron is very strong up to 231$m\mu$ but weak afterwards. It is therefore very suitable for use with this combination.

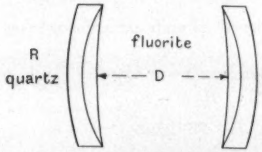

Fig. 1

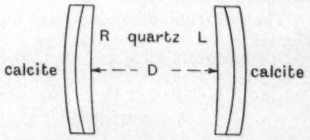

Fig. 2

The data for a focal length of unity are as follows (see Fig. 2):

$$R_0 = 0{\cdot}421366 \qquad R_2 = R_4 = 0{\cdot}273690 \qquad R_6 = 0{\cdot}842733$$

$$R_8 = -R_6 \qquad R_{10} = R_{12} = -R_2 \qquad R_{14} = -R_0$$

$$t_1 = 0{\cdot}01250 \qquad t_3 = 0 \text{ (air)} \qquad t_5 = 0{\cdot}017133$$

$$t_9 = t_5 \qquad t_{11} = t_3 \qquad t_{13} = t_1$$

$$D \text{ (vertex to vertex)} = 0{\cdot}150$$

$$F = 1{\cdot}0$$

DOUBLE REFRACTION

This is made negligible by making in either combination the two quartz elements of right and left rotation quartz respectively, both these, and in the quartz-calcite combination the calcite elements, being cut perpendicularly to the axes of the crystals.

Cement

These combinations, although shown without it, may be cemented, provided that a cement be used which is transparent within the extent of the wave-lengths cited. Such a cement was discovered by the writer and described in these *Transactions**. This cement consists of what is known in the trade as "syrupy dextrose," and is impure grape sugar. The point is that, as far as experience goes at present, it will not crystallise out and it behaves much like balsam, drying very slowly, probably on the outside only. In the hope of getting something better, the writer obtained some pure dextrose from Messrs Kodak, Ltd., in the form of crystals. This dissolved freely in distilled water, but quite soon dried and crystallised out and was therefore discarded. The commercial "syrupy dextrose" was obtained from Messrs Harrington Bros. The thin film of this required for cementing a doublet transmits the whole of the ultra-violet up to $223m\mu$ without appreciable loss. A layer 1 inch thick transmits to the same limit but requires ten times the exposure.

Light Filters

Of course, in order to use these rapid rectilinear combinations effectively, it is necessary to exclude the visible spectrum. The light filters which do this, as far as the writer knows at the present time, only transmit the longer waves of the ultra-violet. There are several that transmit the visible spectrum as well which

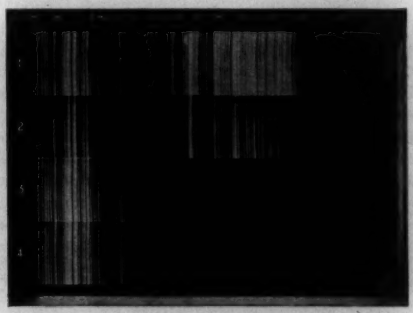

Fig. 3. 1. Two quartz panes, each 3 mm. thick, cemented with dextrose.
2. Windolite. 3. Vita glass. 4. Schott's uviol crown

go much farther; indeed one of them, Windolite, reaches $233m\mu$, but is not suitable for optical purposes in its present form. Photographs of the spark spectrum of iron, taken with the same exposure through some of these light filters, are shown in Figs. 3 and 4.

* *Trans. Opt. Soc.* **29** 1927–8 (20).

As regards these ultra-violet filters, much work remains to be done, but by using films which are not appreciably sensitive to the visual spectrum much the same end may be achieved without them. In this respect a pure bromide film as used for lantern slides is very helpful.

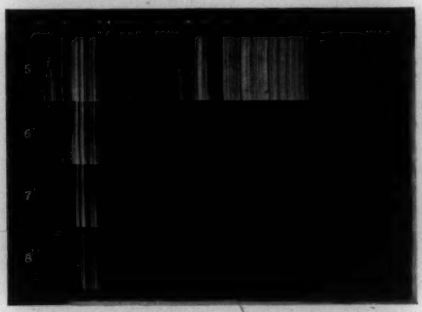

Fig. 4. 5. Two quartz panes, each 3 mm. thick, cemented with dextrose.
6. Schott's ultra-violet blue glass. 7. Chance's ultra-violet filter.
8. Wratten's ultra-violet filter

DISCUSSION

Prof. A. F. C. Pollard: I presume that Col. Gifford designed the fluor-quartz combination primarily for photography by artificial ultra-violet illumination rather than for photography by sunlight. The limit of the solar spectrum on account of atmospheric absorption is generally about 2920 Å.U., but a line as short as the silver line 2446 Å.U. has been chosen for computing this combination. Possibly Col. Gifford can say if this matters in practice, but it certainly would be interesting to compare two critical photographs of the same object illuminated artificially and by sunlight.

Mr T. Smith: The figures given by Col. Gifford for the chromatic aberration should be of interest to all who may think of using these particular combinations of materials, for they will apply with very little variation to lenses of various forms.

I would like to give one caution in connexion with the spectra shown in Fig. 3. It is claimed that improvements are continually being made in Vita glass, so that any one spectral record will only refer precisely to a specimen produced at a given period.

Prof. A. O. Rankine: I wish to suggest that Col. Gifford should be asked if possible to insert in his paper the thicknesses of the glass light filters relating to Figs. 3 and 4, so as to make more precise the comparison with quartz.

Prof. L. C. Martin: It is possible that a *trace* of glycerine added to the pure dextrose might make it sufficiently hygroscopic to prevent crystallisation.

Perhaps if Vita glass and the newer American and German glasses of the same kind are sufficiently improved, these materials may have interesting possibilities for the construction of ultra-violet lens systems.

Col. Gifford has in this paper drawn attention to very valuable properties in achromatic quartz-fluorite combinations which have had little use so far but may have considerable future importance.

Mr C. Beck: Col. Gifford's paper is a valuable addition to the technique of ultra-violet photography. The fact that at this moment the demand for a photographic lens to work with only ultra-violet light is not pressing only means that in this as in his spectroscopic work Col. Gifford is a pioneer and it would not be long before such a lens would be required.

It would be very desirable to know whether any samples of fluor spar could be obtained which are free from fluorescence. The production of an achromatic ultra-violet object glass for the microscope is an urgent need, but the materials used must be quite free from fluorescence, as even quite a minute portion of scattered light is enough to obliterate the images of many of the delicate objects examined with the microscope which depend for their recognition on very small contrasts of light and shade.

Mr Z. A. Merfield: It might be of interest and not out of place in connexion with this paper, if I may be permitted to do so, to refer to some experiments I have recently made in connexion with the transparency of quartz and other substances in the extreme ultra-violet. The usual method of testing quartz intended for optical purposes is to examine it visually between crossed nicols. By this means twinning, etc. are easily detected, provided the experiment is properly arranged. If a sample of quartz, which has been found by the above method to be free from twinning and is clear and has all the appearances of being homogeneous, be now examined on a photographic polarograph using ultra-violet light, opaque patches will invariably be detected in it. The shape of these opaque patches leads one to believe that they have something to do with twinning, but I must point out that the same patches can also be detected merely by photographing the sample in ultra-violet light or simply laying it on an oiled photographic plate and giving a short exposure to, say, $\lambda = 275 m\mu$. Sometimes the patches are detected with one wave-length, sometimes with another. The cause of the phenomenon is rather obscure and seems to warrant further investigation, seeing that quartz is used in optical instruments, especially on account of its supposed transparency in the ultra-violet. Fused quartz which has been slowly cooled also shows the same peculiarity. A sample of quartz, free from twinning and apparently perfect in every respect, when cut into a form suitable for an oscillator invariably has resonance points which are unexplained by its dimensions. This, too, seems to point to some want of homogeneity. Quartz is not the only substance in which

these opaque patches can be observed. I would like to ask Col. Gifford whether he has observed this phenomenon or if he could throw any light on its cause.

Col. Gifford (communicated): In reply to Prof. Pollard, these combinations were both designed for use on objects illuminated by rays from 3962 Å.U. to the limit of about 2100 Å.U. shown in the tables in the case of quartz and calcite, absorption occurring at 2062 Å.U. They were not intended for use with sunlight but rather with a spark spectrum in these shorter wave-lengths, such as that of iron. Provided the reflecting power of the object extended to shorter wave-lengths than 2920 Å.U., there would doubtless be a marked difference between photographs of an object taken in this way and one taken by sunlight.

With regard to the point raised by Mr Smith, I have tried only one specimen of Vita glass, but have no doubt that the meltings vary a little.

The thicknesses of the different filters in millimetres are:

Cemented quartz	6·096	Schott's ultra-violet blue glass	3·099
Windolite	0·508	Chance's ultra-violet filter	1·880
Vita glass	2·692	Wratten's ultra-violet filter	5·867
Schott's uviol crown	3·150		

Attempts were made to prevent the crystallisation of the pure dextrose in the way suggested by Prof. Martin, quantities of glycerine varying from a few drops to about 10 per cent. being added, but each experiment resulted in crystallisation within a few days. The syrupy dextrose seems to be the only form which is permanent. The help of an expert analyst is required here.

It is certainly to be hoped that when the newer glasses are improved they may be sufficiently transparent to take the place of quartz, calcite, and fluorite, but the fact that the slightest impurity brings melted quartz to the restricted condition of glass seems rather against it.

The point raised by Mr Beck is an important one. It is not one to which I have paid much attention, but I have just tested my own stock of fluorite, all of which was obtained from a large lump found by me in Switzerland many years ago, and I find it very free from signs of fluorescence. The source of illumination was the condensed cadmium spark focussed by a quartz lens. I have, of course, seen more fluorescent examples.

I have not observed the phenomenon referred to by Mr Merfield and am afraid that I can throw no light on it. It would be interesting to know whether the patches referred to occur under X-rays.

SOME REMARKS ON OLD ENGLISH OBJECTIVES

By H. BOEGEHOLD, Ph.D.

[Communicated by Mr T. Smith.]

MS. received, 14th July, 1928. *Read and discussed, 11th October*, 1928.

During the preparations necessary for adequately judging the life work of L. J. Schleiermacher (b. 1785, d. 1844) I came across an old Ramsden telescope, bought probably towards the end of the eighteenth century and since then in the possession of the Schleiermacher family. Through the kindness of the present senior member of this family I was allowed to have two plane surfaces ground on the lenses of the objective in order to ascertain the indices with the refractometer.

As was to be expected, the material turned out to be the ordinary English crown and flint glasses of that time. I am indebted to my colleague Dr H. Kessler for these measurements; he told me at the same time that there was a very marked stria in the flint glass without, however, having a deleterious effect on the image. The indices and ν-values are as follows:

$$n_1 = 1{\cdot}5316,\ \nu = 58{\cdot}9;\quad n_2 = 1{\cdot}59858,\ \nu = 37{\cdot}7.$$

At the same time I had the radii and thicknesses measured and a trigonometrical calculation was made. After our customary reduction to $f' = 500$ mm. (nearly 20 in.) for telescope objectives I obtained for the above-mentioned lengths the values indicated under Fig. 1, which shows the appearance of the surfaces in a meridian plane. The figure was reduced to about natural size for the sake of comparison with similar figures in former volumes of these *Transactions*; the same was done with Fig. 2, which shows the spherical aberration of the direct pencil.

If we turn our attention to the work of Ramsden's successor Berge*, we find a very marked similarity in the aberrations, Ramsden's curve proving slightly better than Berge's. The radii are somewhat different, but, remembering the subjective way then in use of obtaining the relation of the two dispersive powers of the glasses, we do not wonder at the different results notwithstanding the similarity of the material used.

In general there would be no reason for pointing out the similarity of work done by the master's successor. The reason for doing so here is because of Mr Baxandall's interesting remark (p. 293 of the paper cited) that in some cases the lenses in Ramsden's instruments were ground by P. Dollond, his brother-in-law.

Prof. v. Rohr tells me that he hopes to publish soon, together with Mr T. H. Court, Sulzer's report about his visit to Ramsden in 1790 in order to bring it to the knowledge of English readers. From this report of an eyewitness we learn

* See *Trans. Opt. Soc.* **27** 1925–6 (279–80).

that—in 1790 at least—Ramsden was amassing large quantities of glass for his manufacture of telescope objectives. A great part of them will have been binary systems, and we may conclude that Berge, his pupil and successor, was brought up to the same knowledge. If this is conceded we may look on Figs. 1 and 2 as fair specimens of Ramsden's own work and consider Berge's figures cited above as a satisfactory corroboration. As to the time and conditions of his buying ready-made lenses from his brother-in-law (more precise knowledge on this point would be of great interest) a calculation of Berge's and Ramsden's objectives can evidently furnish no information.

Fig. 1. Objective of Ramsden telescope. Actual size for $f' = 500$ mm. Radii, thicknesses, and separation in mm.

$r_1 = +121{\cdot}0$	$d_1 = 2{\cdot}98$
$r_2 = -328{\cdot}8$	$b = 0{\cdot}25$
$r_3 = -219{\cdot}7$	$d_2 = 2{\cdot}52$
$r_4 = +453{\cdot}8$	

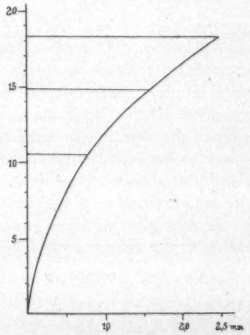

Fig. 2. Spherical aberration of Ramsden objective

DISCUSSION

Mr T. Smith: Our warmest thanks are due to Dr Boegehold for providing us with these measurements. Apart from their value in connexion with the point raised by Mr Baxandall, it should be extremely interesting to us to have such quantities recorded for as many as possible of the telescopes made in the time before Fraunhofer's discovery had reduced the exact determination of a refractive index to a simple and sure measurement. It is surprising, considering the difficulties which must have been experienced when refractive indices and dispersions were so uncertain, that the standard of correction attained in these instruments should have been so high.

Mr D. Baxandall: We are greatly indebted to Dr Boegehold for this further contribution to our knowledge of old English objectives. On the point which he has raised I agree that more precise knowledge is desirable. Kitchiner's "Beauclerc" telescope, to which I previously referred, was purchased by him at the sale of Aubert's instruments at Sotheby's in 1806. Ramsden's name was engraved at the

eye-end, but the objective was made by Peter Dollond, who, sometime during the period 1806–1815, engraved his own name on the tube, at Kitchiner's request (Kitchiner's *Practical Observations on Telescopes*, 1815 ed., pp. 64, 65). The triple objective had an aperture of $3\frac{3}{4}$ inches and a focal length of 46 inches.

In the Science Museum there is a $2\frac{1}{2}$-foot achromatic telescope with 2-in. double objective. It is engraved "Ramsden, London" at the eye-end, and, according to an old manuscript note pasted inside the lid of the case, it was made for Ramsden by Peter Dollond. There is evidence that the instrument belonged to Dr Lind, F.R.S., in 1769.

Mr T. H. Court: Although it is well known that Peter Dollond occasionally made the objectives for his brother-in-law Ramsden, it must be remembered, on Dr Kitchiner's authority, that Ramsden had his own glass shop and was a fully competent glass grinder. Thus we may assume that the lenses found in telescopes bearing Ramsden's signature will generally be of his own manufacture. Probably in the exceptional cases, when we know that a Dollond objective was used, it was to meet the desire of a client to possess an instrument that combined Ramsden's skill as a mechanician and Peter Dollond's experience of the achromatic lens.

One must not forget, however, in any critical examination of these old instruments that in many of them the original object glasses have been replaced by more modern ones, either because the old lenses have been broken or lost or some subsequent owner desired to improve the performance of the instrument.

A systematic examination of the achromatic objectives of such makers as Adams, Watkins, Gilbert, Martin, and other 18th-century telescope makers on the lines of this investigation by Dr Boegehold would be of great value both because it would no doubt make it possible to identify the individual characteristics of the makers and because it would also throw light upon the extent of Dollond's influence.

Dr Boegehold: I am very glad that my paper has given rise to such an interesting discussion. It is to be hoped that possessors of telescopes belonging to this period will allow them to be measured, for it is only in this way that we can obtain a wider and more accurate knowledge of the telescopes made by the old English manufacturers.

REVIEWS

Standards of Nomenclature and Measurement of Ophthalmic Products: recommended by the Ophthalmic Optical Standards Committee and adopted by the Institute of Ophthalmic Opticians and the Association of Wholesale and Manufacturing Opticians, 1927.

Until the publication of this report, the standards in existence relating to spectacle and eyeglass ware were those recommended by the Optical Society Standards Committee. This Committee produced two reports, one dealing with Spectacles and Eyeglasses and the second with Trial Cases, which were adopted by the Optical Society on 16th May, 1904, and 18th June, 1908, respectively.

Since that time considerable development has taken place in the science and technique of ophthalmic optics and in the industry connected with it. More refined methods and instruments have been evolved for the determination of optical and muscular anomalies of the eyes, leading to enhanced accuracy at all stages of the work. The large increase in the number of cases where astigmatism is established has greatly augmented the number of astigmatic lenses, sph-cyl and toric, prescribed; muscular anomalies and the prescribing of prisms and exercises receive far more attention than heretofore; the hand ophthalmoscope is widely used by opticians, and large table instruments have been devised and improved for ophthalmoscopy, objective determination of ametropia, and microscopical examination of the eye. The better understanding of the problem of spectacle lens design has led to a great increase in the use of bent meniscus and toric lenses on standard base curves, to a realisation of the importance of vertex power in spectacle lenses, and to a commencement in the practical adoption of "best form" lenses.

The work of Sir Wm. Crookes and others on the effects on the eye of ultra-violet and infra-red radiations has focussed attention on the subject of eye protection resulting, in spite of contradictions in parts of the evidence and in varying interpretations thereof, in a few reliable glasses.

Substantial strides have been made in the production of fused and solid bifocals, many of which are beautiful examples of the glassworker's art.

Spectacle lenses have gradually become larger; the available varieties of spectacle frames and eyeglasses, and the materials and methods used in producing them, have extended enormously.

In view of this marked development, it is not surprising that the Optical Society standards of 1904–8 were proving somewhat inadequate in certain directions and that the need was felt for revision.

The report is divided into six sections:

(1) Nomenclature of Frames and Mounts,
(2) Measurements of Frames and Mounts,
(3) Nomenclature of Ophthalmic Lenses,
(4) Measurements of Ophthalmic Lenses,
(5) Standards for Trial Cases,
(6) Abbreviations and Symbols for Prescription work,

each of which appears to have received detailed attention during the thirty or more meetings the Committee has held since October, 1922.

The report would have been a more valuable document had the list of recommendations been accompanied by brief explanatory paragraphs setting forth at least the general principles the members of the Committee were seeking to promulgate. Such a course may have provided reasons for a number of the recommendations which, as the report stands, call for comment.

SPECTACLES

TYPES OF BRIDGES.

A (*Arch*)—this is a departure from the O.S. term *U* (*Arch*).

Chinese—this, an addition to the O.S. list, is practically a W bridge, always low and inset, with shallow arch and wavy shanks. Is it sufficiently important for a separate classification?

STYLES OF RIMS.

The term *rim* displaces the O.S. word *eyewire*.

The old *solid wire* style for grooved lenses is now renamed *invisible*, which scarcely appears to be an improvement.

TYPES OF JOINTS.

Five types are listed: English (E.J.), American (A.J.), Pea, Reversible, and Nutcracker.

May not the reversible joint be either English or American in form? The nutcracker joint again is reversible, and as the frames on which it is used ordinarily carry heavy lenses, the joints become unstable; in view of the scarcity and expense of this joint and of the fact that either the English or American type can be adapted to the same end, its inclusion as a standard seems questionable.

SPECTACLE MOUNTS

These are now included in a separate Section.

PARTS OF A STRAP.

The part here called a *clamp* has ordinarily been called a *strap* in practice, the term clamp being widely used to name the metal piece gripping the modern shell or imitation shell rims. What is here called a *post* has been extensively known as a *stud*.

EYEGLASSES

PARTS OF A RIGID AND SEMI-RIGID.

The old workshop term *receding piece* gives way to *inset* (or *offset*) which is unlikely to diminish the confusion frequently arising in dealing with this part of an eyeglass.

STANDARD MEASUREMENTS OF FRAMES AND MOUNTS

HEIGHT AND PROJECTION OF BRIDGE.

The measurements are made from the "inner" bearing surface; the word "inner" is scarcely necessary.

SCREWS.

The Optical Society wisely adopted the already existing British Association Standard thread. The new Committee have for some reason recommended as standards three threads which do not appear in any of the generally known standards, the nearest approach being numbers 9, 12 and 15 of the British Association and the Thury (Swiss) threads. Measurements made on a spectacle joint screw and a glass screw taken from a box of screws as at present supplied for spectacle work agree with the recommended sizes; it would almost appear as if the Committee desire to set up yet another standard set of screw threads specially for spectacle work.

STANDARD NOMENCLATURE OF OPHTHALMIC LENSES

PERIPHERAL FORMS OF LENSES.

The term *oval* has been replaced by *regular oval*, which is a doubtful improvement. The *short oval*, omitted by the Optical Society, has been incorporated. The confusing term *round oval* has wisely been modified to *pantoscopic round oval*, a term of long standing in the industry.

LENS SIZES

SHAPES OF LENSES.

The difference of 10 mm. between the axes in the *long oval*, which has heretofore been 12 mm., is a scarcely perceptible difference between *regular* and *long* ovals.

BIFOCAL SEGMENTS.

It is hoped that the fixing of three standard segment diameters (19, 32, and 45 mm.) will not be so rigidly enforced as to discourage any attempts a refractionist may make to satisfy the optical conditions of his bifocal problems.

STANDARDS FOR TRIAL LENSES

It is recommended that trial lenses be plano-convex and plano-concave in both the sphericals and the cylinders, the lenses being marked with their true powers. No reference is made to the neutralisation method of testing lens powers, the chief advantage of the proposed lenses being given as "the ability of the optician closely to imitate, in the trial frame, the lens that the client will subsequently wear, and that any modification in the correction that may be necessary owing to effectivity changes due to transposition of the lenses in the trial frame, may be made by the optician before the final selection of the lenses to be ordered."

The question of the best form of trial lenses seems to involve more than this. In the complete process of determining a subject's refraction and fitting him with the requisite correction, there are three main stages:

(A) the determination of the refraction and writing of the prescription to represent the effect on the eye of the trial lenses used;

(B) the making of the spectacle lens by the manufacturer to produce this effect when correctly positioned;

(C) the checking by the refractionist of the lens supplied.

If the back surface of the spectacle lens is to occupy the same position relative to the eye (spectacle point) as the back surface of the trial lens combination, then in order that the two shall have the same effect on the eye in both distance and near vision, they must have equal equivalent powers and back vertex powers (B.V.P.) and the principal planes of the one must occupy the same positions as those of the other. This cannot be achieved in practice, and we take advantage of the accommodative adaptability of the eye in near vision in that we are content to aim at obtaining equal back vertex powers only.

If then we take care to provide the refractionist with trial lenses of such a form that he is able, without complications, to write out a prescription that represents closely the B.V.P. of the correction; even if, to go further, we enable him to imitate in the trial frame the actual spectacle lens the subject will subsequently wear; and if the manufacturer supplies, as he can easily do, an equally effective spectacle lens, then the refractionist should be in a position to check this B.V.P. when he receives the lens. The effort made to carry out stages (A) and (B) correctly will otherwise be largely wasted.

At present the large majority of refractionists check their prescriptions by neutralisation, the test lens being placed of necessity on the convex *front* surface of the spectacle lens if this be of meniscus or toric form, so that it is the front vertex power that is tested. Plano trial lenses, as such, would have no advantage over symmetrical lenses at this stage (C) of the process.

The trouble would be overcome if the refractionist could determine the B.V.P. of the trial lenses *in situ* with a vertex power instrument, enter this on his prescription and check the lens supplied with the same instrument. (This would not be easy with the trial lenses sitting loosely in the cells of the trial frame.)

Failing this, the solution must be a compromise; fortunately the errors made are not always cumulative and for the more ordinary refractive errors are not large. Plano trial lenses, even if the cylinder were placed behind the sphere, can imitate meniscus and toric lenses only approximately. A compromise giving promise of the accuracy required would appear to consist in:

(i) the use of thin plano trial lenses of small aperture, the refractionist placing them in the trial frame with their *curved* surfaces towards the eye, so that the refractive effect of the sphere would not be modified by any material following it and the effect of the last surface of the cylinder (presumed placed in front of the sphere) modified to the least extent possible;

(ii) either [*a*] the positive spectacle lenses being checked with the thin plano negatives of aperture small enough to enable the plano surface to be approached very nearly in contact with the back surface of the spectacle lens;

or [*b*] the provision of a table connecting front and back vertex powers of positive lenses of different forms, enabling the refractionist to neutralise the former and determine from his table whether the result corresponds to the back vertex power required of the lens.

There is the additional advantage of small aperture trial lenses that patients are constrained to look squarely through them.

It is proposed that prisms be mounted "with one surface parallel to the mounts, the powers...to be measured with the *remote* surface of the prism parallel to the test chart." The term "remote" is rather ambiguous.

To obtain a measure of agreement among the many parties interested in such a matter as standardisation, whether it be of nomenclature, symbols, conventions, materials, methods or what not, is, as those who have attempted the task appreciate, extremely difficult. The members of the Ophthalmic Optical Standards Committee held, it is stated in their report, over thirty meetings and have without doubt performed a useful service in arriving at agreement on points so numerous. The impression obtained, however, after a scrutiny of the report is that too much weight has been given to matters as they are found to exist in the industry at present, insufficient regard having been paid to probable developments in the future and to a principle of classification demanding the reduction of the number of types to a minimum.

H. H. E.

Ophthalmic Lenses. By H. H. EMSLEY, B.Sc., and WM. SWAINE, B.Sc., F.S.M.C. Pp. vii + 319; 128 Figs. (London: Hatton Press, Ltd., 1928.) Price 15*s*. net.

This book, based on courses of lectures given by the authors, has been written in the hope that it will fill a gap in the literature available for students who aim at a career as ophthalmic or dispensing opticians. The authors point out that the first eleven chapters contain what must be grasped by those who would understand the matters of everyday practice in these occupations. The remaining six chapters deal with the somewhat more theoretical problems connected with image formation, but include nothing which should not be fully understood by any competent optician.

No one can read the book without realising that the authors have succeeded admirably in their aim. The work is well planned and liberally illustrated. The language is clear and simple, and each point is made in that direct yet unhurried manner which betokens the skilled teacher. The authors have been wise enough not to attempt too much. They have considered with care what it is essential for the man or woman engaged in these occupations to know, and what may safely be omitted. Having decided upon the ground to be covered, they have expounded the properties of the systems they consider in a manner intelligible to all educated readers, including doubtless many to whom no existing book on geometrical optics conveys any meaning. In short, the book needs no other justification or recommendation than that there is not another like it.

A critical perusal of the text shows that the authors have taken great pains to avoid any statements which might in any way be misinterpreted. In only one place was any opening for error noticed, and there a mistake could only arise through the reader mentally adding what the authors themselves have carefully refrained from stating.

As the book is intended for students, many exercises have been added at the end of each chapter for the student to attempt. Answers to the exercises are given in a separate section.

At the end of the book many useful tables have been collected together. Several of these are new, and should be useful to optical practitioners. The only adverse criticism to be made of the whole volume is that some further explanation of a few of these tables should have been given. For example, if an explanation has been given anywhere of the stepped line in Table XV it has been very successfully hidden.

It would be a great pity if it were thought that this is only a student's book. It is in reality a volume which will not fail to prove of value to any one whose work concerns ophthalmic lenses. On this subject it forms a valuable book of reference.

In conclusion warm praise must be given to the publishers for the way in which the book has been produced. The type and the illustrations are very clear: the text is remarkably free from misprints: finally, the size of the book is convenient for handling.

T. S.